SUMMER AND AUTUMN PRESSURE ANOMALIES AFFECTING WINTER TEMPERATURES IN THE UPPER MISSISSIPPI VALLEY [1]

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The region of the upper Mississippi Valley is an area in which the winters differ greatly in temperature. Some are almost continuously cold; others are moderate with only brief cold periods. The average temperature at St. Paul during the winter, December, 1874–February, 1875, inclusive, was −5.5° F.; for the winter of 1877–78 the average was 29.1° F., giving a range of 23.6° F., a range greater than the average difference between the winters at Boston and Charleston. In the 30 years from 1889 to 1919 there were eight cold winters in this region, during which the average temperature departure in the States of Minnesota and Iowa was −5° F., all but one being more than 3° below normal. In the same period there were eight warm winters with an average departure of 4.6° F., all greater than 3° F. That is to say, half the winters showed marked departures from the average. Table 1 shows the departures by months during these eight cold and eight warm winters.

TABLE 1.—*Cold and warm winters in the upper Mississippi Valley, 1889–1919*

Year	Minnesota				Iowa			
	December	January	February	Season	December	January	February	Season
1892–93	−4.4	−7.8	−5.4	−5.9	−5.2	−9.2	−6.6	−7.0
1893–94	−5.2	−2.4	.5	−2.4	−2.1	.8	−2.9	−1.4
1898–99	−3.4	.4	−7.5	−3.5	−6.0	1.3	−10.4	−5.0
1903–4	−5.5	−5.0	−9.7	−6.7	−4.5	−4.5	−7.8	−5.6
1909–10	−5.3	2.3	−4.5	−2.5	−9.0	−.4	−4.8	−4.7
1911–12	4.1	−16.2	−1.4	−4.5	3.8	−14.3	−4.5	−5.0
1916–17	−7.4	−6.5	−9.9	−7.9	−5.4	−1.5	−7.4	−4.8
1917–18	−10.1	−9.0	1.4	−5.9	−9.6	−9.9	.4	−6.3
1889–90	13.1	−1.9	3.2	3.8	11.7	−.5	2.5	4.6
1890–91	6.0	10.0	−2.6	4.5	4.4	7.5	−3.2	3.2
1891–92	9.8	−2.1	6.0	6.4	8.2	−3.2	5.5	3.5
1895–96	3.0	3.0	5.9	4.0	1.3	4.9	4.8	3.7
1905–6	5.3	7.5	1.8	4.9	2.9	6.1	1.0	3.3
1907–8	6.0	6.9	5.9	6.3	4.7	6.4	1.7	4.3
1913–14	10.8	7.4	−9.2	3.0	7.9	9.3	−5.8	3.8
1918–19	7.5	9.0	1.0	5.8	8.6	8.3	2.3	6.4

The immediate meteorological causes of these large variations are evident; a change in the paths and frequency of moving cyclonic and anticyclonic centers brings much polar air to this region one winter and much southerly air another winter. These changes in track which persist long enough to give a decided character to a month or a season are associated with changes in the pressure distribution in the North Pacific, especially with changes in the position and intensity of that "fluctuating area of low pressure in the North Pacific near Alaska," commonly called the Aleutian LOW.

The fluctuations of this area and of the pressure in the northern half of the Pacific generally are connected with slow, antecedent, and coincident world-wide changes in the general circulation. This is abundantly shown by the numerous correlations discovered by Walker, Clayton, and others, and notably by the coefficients of very high value recently calculated by Groissmayr.[2] He found a definite influence of the weather factors of India, January to October, on the following winter in Canada, getting for Winnipeg temperatures the remarkable partial correlation coefficient of 0.81.

The warm winters are preceded by a belt of summer deficit across the Pacific, generally including a portion of the west coast of the United States or Canada, and Hawaii, the Philippines, and China, but sometimes displaced northward to include Alaska, Siberia, and Japan, with pressure above normal at Honolulu and Manila. The autumn deficit is centered over Alaska in all cases for which Alaskan data are at hand.

From year to year these areas of excess and deficiency differ enough in position and extent frequently to invalidate forecasts based on correlations or formulas using individual stations, while remaining recognizable as belonging to one or the other of these types.

These statements are descriptive of the conditions which prevailed during the 16 years examined, and are offered as indicative of the value of further investigation rather than as final precepts. Of the 14 remaining winters in the period, 1889–1919, which were not markedly abnormal as a whole, there were several types. In a few the departures were small in all three months and in both Iowa and Minnesota. In others there were large departures in one direction for a part of the winter and in the opposite direction for the remainder of the winter, sometimes beginning warm and ending cold and sometimes the reverse. In still others the departures in Iowa and Minnesota were of opposite sign. These years, presenting so many intermediate types of temperature distribution, and hence probably of pressure distribution, will be left for future discussion.

Fig. 1 shows the average departure from normal pressure in the Northern Hemisphere during the eight summers, June, July, and August, preceding the eight cold winters given in Table 1. Pressure averaged low over northern Europe and over northeastern Asia and Alaska, but a belt of moderately high pressure extended from western Europe across Iceland, Greenland, and North America, and thence westward to Hawaii, Japan, China, and central Asia. In the autumn months (fig. 2) the western deficit has shifted eastward and the Pacific area of excess has moved northward and increased, Alaska changing from deficit to decided excess. Figure 3 for the winter shows further increase and eastward drift of the Pacific center of excess, and makes evident why these winters were cold in the upper Mississippi Valley.

Similar charts for the eight warm winters (figs. 4, 5, and 6) show a distinct reversal of conditions in Pacific and polar areas for each of the seasons. In summer there is a polar area of excess very similar to the previous deficit in northern Alaska and northern Asia and a belt of subnormal pressure from the northwestern United States and western Canada to China. By autumn the deficit has moved northward and intensified, as the previously discussed excess did, and includes the northeastern Pacific, Alaska, and apparently most of the polar region. In winter the deficiency is strongly marked in all northern latitudes and is still centered over Alaska.

These two sets of maps are averages of eight nonconsecutive seasons in each case and may be assumed to represent the average or typical pressure deviations preceding and accompanying cold and warm winters, respectively; but no individual year conforms exactly with the average, and it is necessary to examine the different years to see whether these types reappear in each case.

[1] Presented before the American Meteorological Society, Des Moines, Iowa, Dec 27, 1929.

[2] F. Groissmayr, Met. Zeitschrift, May, 1929, pp. 176–180.

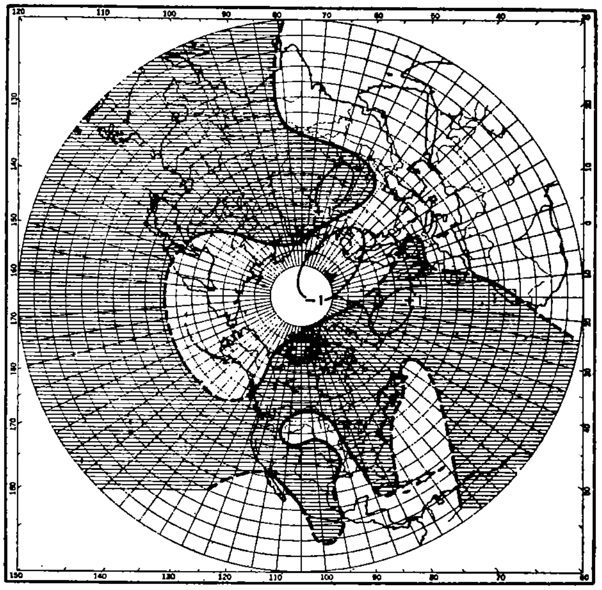


FIGURE 1.—Average pressure anomalies, in millibars, for eight summers preceding cold winters in the upper Mississippi Valley

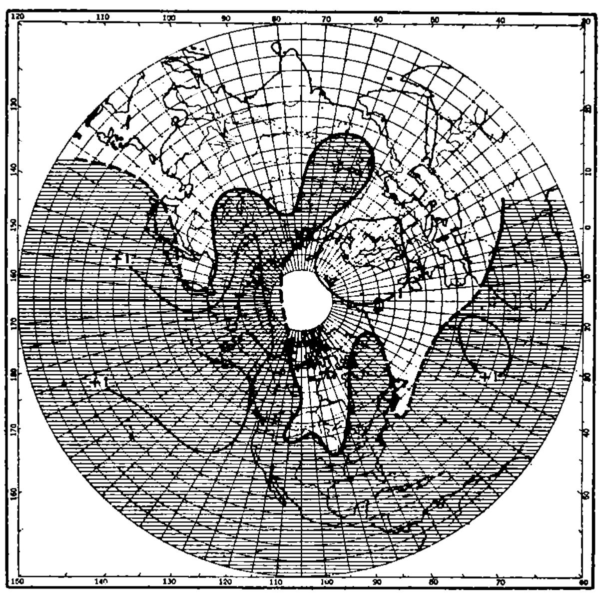


FIGURE 2.—Average pressure anomalies, in millibars, for eight autumns preceding cold winters in the upper Mississippi Valley

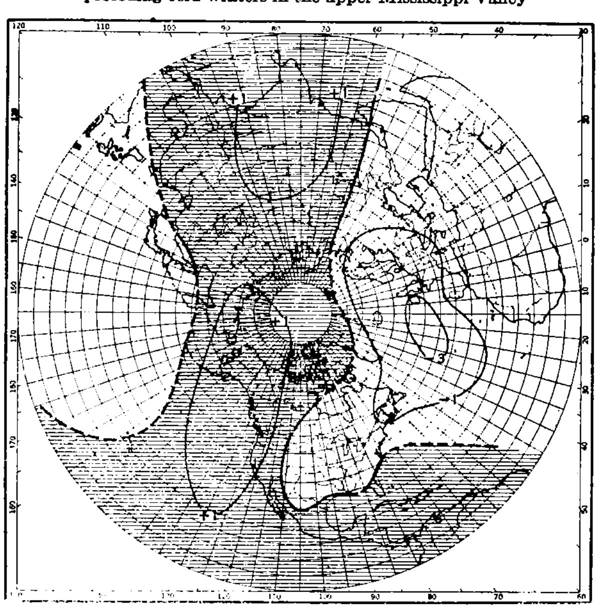


FIGURE 3.—Average pressure anomalies, in millibars, for eight cold winters in the upper Mississippi Valley

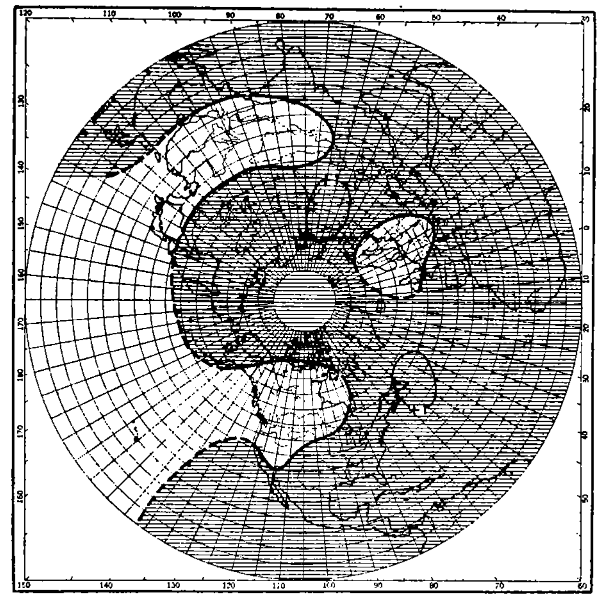


FIGURE 4.—Average pressure anomalies, in millibars, for eight summers preceding warm winters in the upper Mississippi Valley

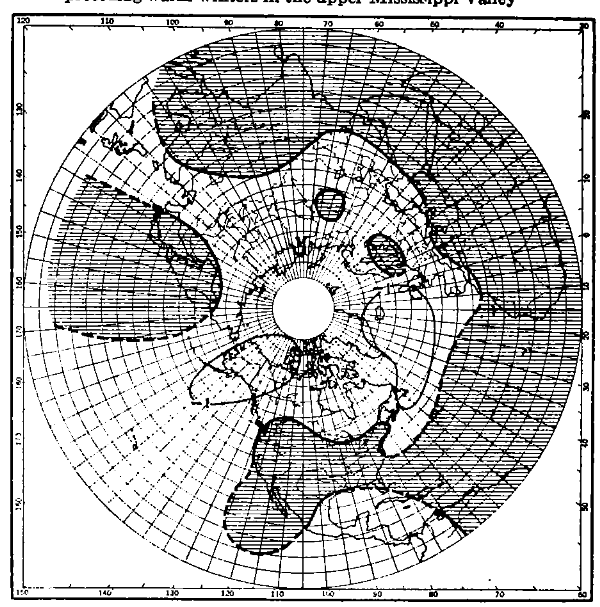


FIGURE 5.—Average pressure anomalies, in millibars, for eight autumns preceding warm winters in the upper Mississippi Valley

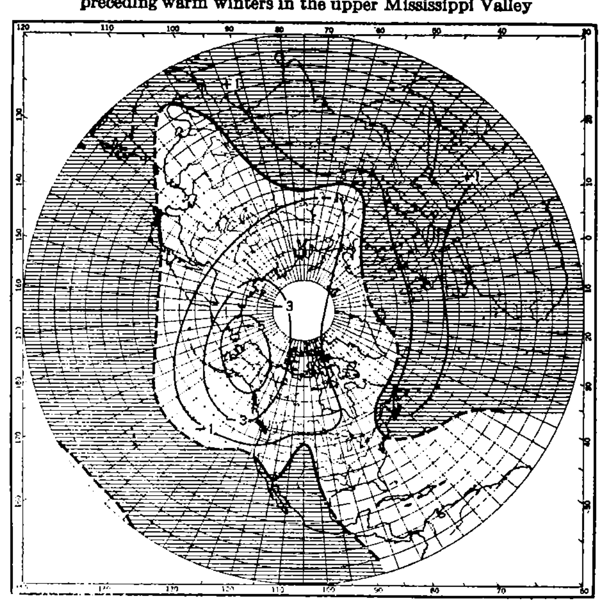
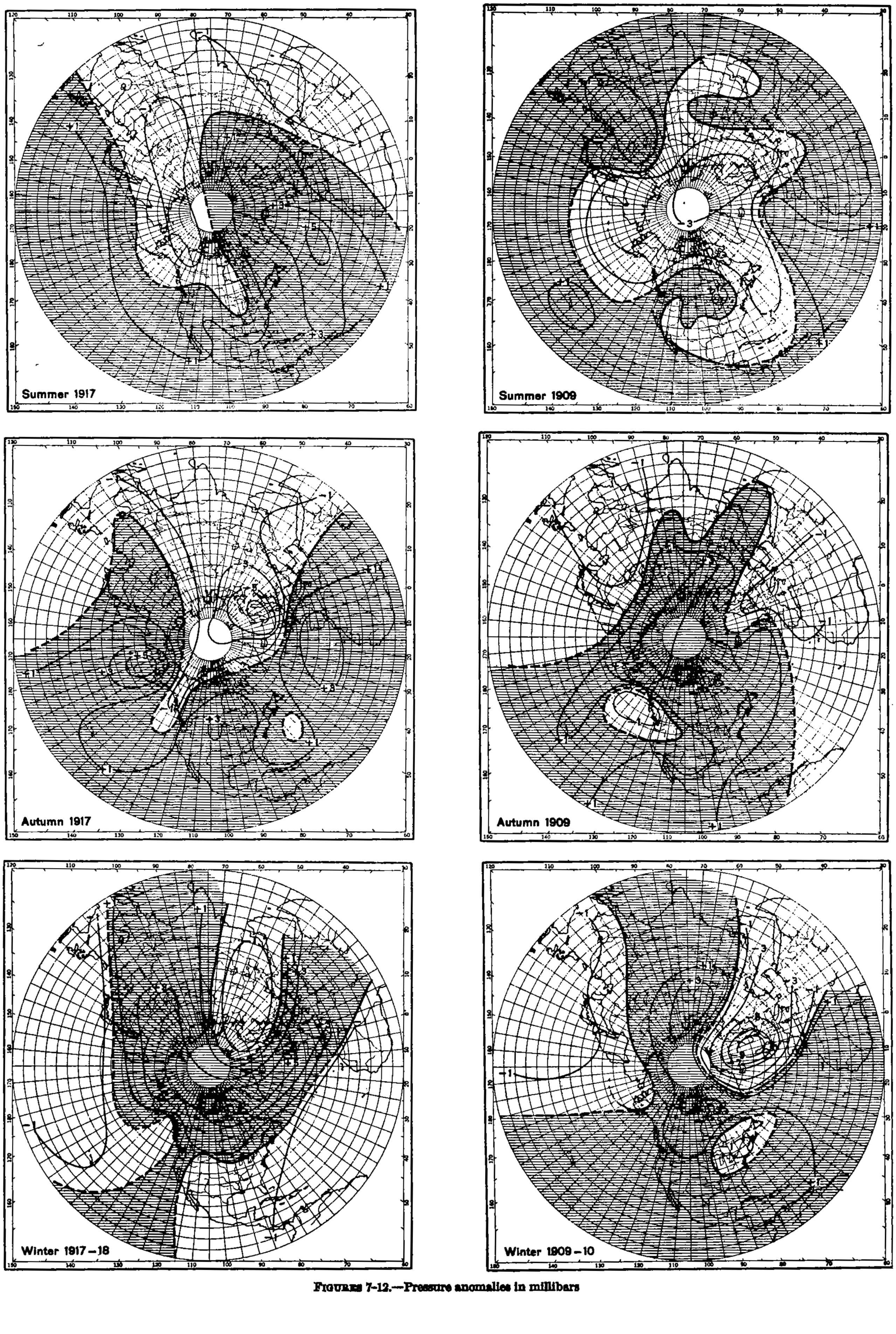
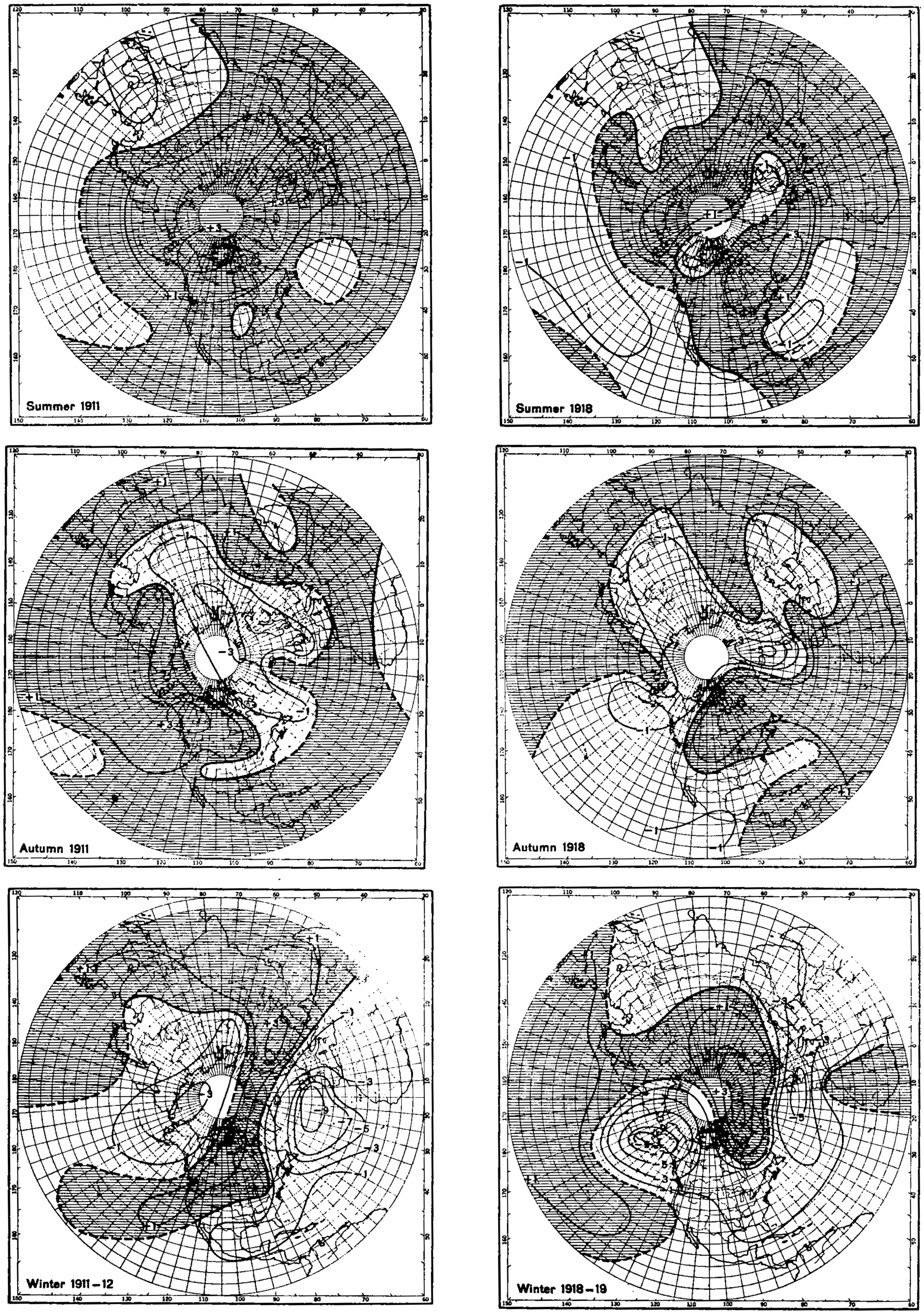


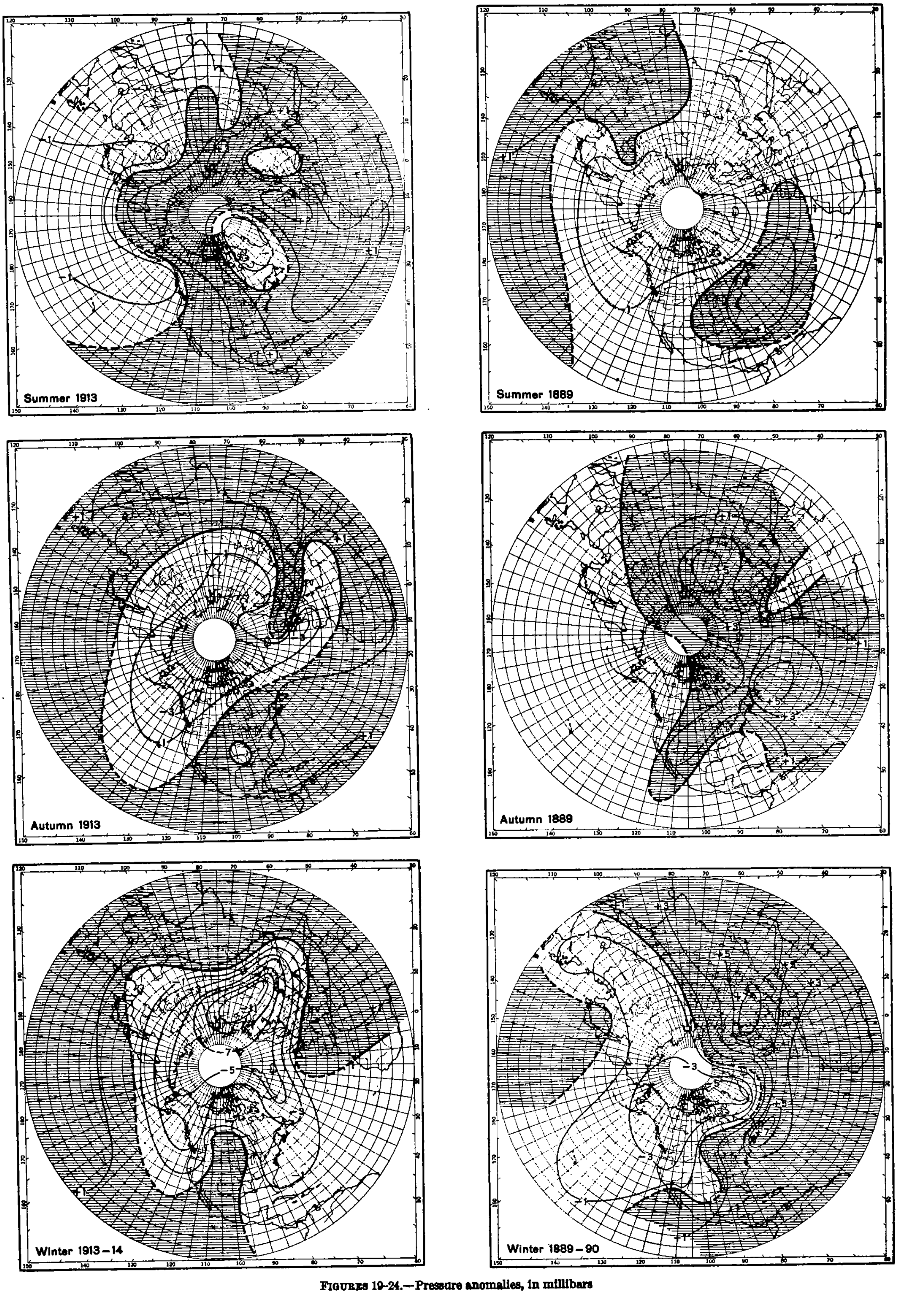
FIGURE 6.—Average pressure anomalies, in millibars, for eight warm winters in the upper Mississippi Valley



FIGURES 7-12.—Pressure anomalies in millibars



FIGURES 13-18.—Pressure anomalies, in millibars



FIGURES 19-24.—Pressure anomalies, in millibars

We have in Figures 7, 8, and 9 the pressure departures during the summer of 1917 and the following autumn and winter. For the summer months there is a deficit over Alaska and most of Canada and an excess from western Europe across the Atlantic, the United States, and the Pacific, with centers over the Azores, Mexico, and Samoa. By autumn, although the tropical regions remain high, the American center of excess has moved northward to Bismarck and the Pacific center to Dutch Harbor, while the deficit has moved from Alaska to Scandinavia. By winter the areas of high pressure have combined in polar regions, as might have been expected from the autumn map. The center of low pressure has decreased in depth and moved eastward, and another deficit has developed in the northern Pacific.

The year 1909 (figs. 10, 11, and 12) shows a similar situation. Again we have a summer deficit over Alaska and an excess over the entire middle North Pacific, greatest near the Hawaiian Islands. In autumn the excess continues at Honolulu but is greatest in Alaska, replacing the summer deficit, and by winter it extends eastward to Greenland. These two years clearly resemble the average cold winter conditions and seem to afford, at least by the end of November, a fairly definite indication that the coming winters will be cold in the upper Mississippi Valley.

There is evident in these records a considerable negative correlation between summer pressure departures at Honolulu and winter temperature departures in the upper Mississippi Valley and a positive correlation between Alaskan summer pressure and the winter temperatures. The year 1911, however, was one of the few exceptions which weakened both these correlations. Using formulas or correlation coefficients, we would predict a warm winter; but, as Figure 13 shows, the pressure distribution was not similar to that of the average warm winter, shown in Figure 4. It has, on the other hand, a belt of high pressure from the western United States across the North Pacific, as in the average cold winter, but that belt is somewhat farther to the north. The autumn map, Figure 14, approaches more nearly the typical cold-winter condition, with center of positive departure over Alaska, and Figure 15 shows the continuation of that center over Canada during the winter. In this season December was warm but January and February were cold.

The reasons for such a close relation between conditions in India and those in Canada, 2 to 12 months later, are not evident, but there is an evident connection between the pressure distribution in the North Pacific and the weather in Canada and the United States. The question naturally arises, then, Do changes in North Pacific pressure manifest themselves long enough in advance to form the basis of seasonal forecasts?

It is the object of this paper to investigate the possible influence of the average summer and autumn pressure distribution in the Northern Hemisphere, and especially in the Pacific area, upon the temperatures of the following winter in Minnesota and Iowa. It deals with seasons only and attempts to discover the types of seasonal pressure distribution, as indicated by deviations from the normal, which preceded the eight cold and eight warm winters previously mentioned. I have used maps rather than correlation coefficients, believing that the former have some distinct advantages over the latter, as will be further indicated in the discussion. The data used are from World Weather Records.[3]

Turning now to some samples of warm winters, the year 1918 offers one typical example, with its summer belt of low pressure entirely across the middle North Pacific from the western coast of the United States to China. (Fig. 16.) By autumn (fig. 17) this has become localized and intensified in the eastern Pacific and western Canada, and by winter (fig. 18) we have the strongly developed low-pressure center over Alaska, which characteristically attends warm winters in the greater part of the United States.[4] The summer and autumn of 1913 (figs. 19 and 20), show a similar distribution of pressure deviations, and Figure 21 another typically warm winter. In this winter December and January were decidedly warm, but February was cold, which possibly was indicated in autumn by the rise to normal pressure at Honolulu.

Of the eight summers preceding warm winters, only one, that of 1889, had a positive pressure departure at Honolulu, and that was small. No Alaskan records are available for that year, but Figure 22 indicates that a belt of low pressure probably extended from western America across the Pacific to Japan, as for the typical warm winter, except more northward, and Figures 23 and 24 show the development of that deficit through autumn and winter.

The maps shown are fairly representative, I believe, of all the years under consideration, so far as can be determined in the absence of Alaskan data for some of the years. They point toward some general characteristics of the pressure anomalies that precede warm and cold winters in the upper Mississippi Valley. In the figures for these 16 years the cold winters are preceded by a belt of summer excess of pressure across the Pacific, generally in middle latitudes, including the west coast of the United States, Hawaii, Japan, and the Philippines, but sometimes displaced northward. In the autumns there are large areas of excess in the north Pacific area, especially in western and northern Alaska, but small areas of deficit may appear to the eastward.

This preliminary inquiry seems to justify extended and careful examination of seasonal pressure deviations and suggests that familiarity with their configurations and their changes from season to season may lead to a system of seasonal forecasting based on their expected movement and alteration, and in that respect essentially similar in practice to the present system of daily forecasting. Such a system would have the evident advantage over a system based on correlation coefficients that each case would be considered for its individual indications rather than as an abstract statistical probability.

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[3] Smithsonian Miscellaneous Collection, Vol. 79 (whole volume), 1927.

[4] A. J. Henry, Weather Abnormalities in the United States, Third Note, M. W. R., 57, 1929, p. 204.

FIGURE 1.—Measurements of the albedo of a snow cover